COMMONWEALTH of VIRGINIA

Tributary Strategy

Goals for Nutrient and Sediment Reduction in the James River

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Virginia Secretary of Natural Resources
Virginia Chesapeake Bay Local Assistance Department
Virginia Department of Conservation and Recreation
Virginia Department of Environmental Quality

EXECUTIVE SUMMARY

Completed in July, 1998, the *Initial James River Basin Tributary Nutrient and Sediment Reduction Strategy* provided information on water quality and living resource habitat conditions in the James River, described the actions taken to date to reduce pollutants, and provided an overview of the kinds of additional management actions that could be taken to further restore the health and productivity of the river. The Initial Strategy document did not contain restoration goals because key information from the Chesapeake Bay Water Quality Model was not yet available. The Chesapeake Bay Water Quality Model results began to become available toward the end of 1998.

In order to provide a forum for stakeholder input to the goal setting process, a James River Technical Review Committee (TRC) was formed. The TRC was composed of representatives from public wastewater treatment facilities, private environmental groups, soil and water conservation districts, industry and local governments. The TRC began to meet in October 1998 to consider the results of various Chesapeake Bay Water Quality Model runs as well as other pertinent information. Staff from the Chesapeake Bay Program office of the U. S. Environmental Protection Agency and State Agencies provided technical assistance to the Committee by analyzing and presenting data from model runs, and by synthesizing living resource information.

State staff has worked closely with stakeholders and technical experts to examine the effects of different pollutant reduction scenarios, and to develop goals that will improve the water quality and living resources of the River. The levels of expected improvements in habitat conditions were analyzed for different combinations of pollutant reduction. Each combination of actions was then evaluated against the critical measures of practicality, cost-effectiveness and equity.

A number of key issues regarding water quality and living resource impacts in the James River were identified during the TRC meetings: sediment load is very high in the James River and suspended sediment reduces light penetration and prevents the growth of submerged aquatic vegetation (SAV); there is no significant problem with low dissolved oxygen levels in the James estuary; nitrogen reduction in the upper tidal James River could promote SAV growth; and chlorophyll levels throughout the James estuary are elevated.

Two special studies on the James River contributed to the discussions on appropriate restoration goals for the James River. The first study, by Virginia Commonwealth University (VCU), focused on living resources in the James River above the fall line and identified substantially impacted benthic communities primarily due to sediment. The second study, by the Virginia Institute of Marine Science (VIMS), established the existence of SAV beds in the upper tidal James prior to the 1940's. Smaller historic beds were identified in the lower tidal river.

The James Technical Review Committee met eight times but failed to reach consensus on appropriate nutrient and sediment goals for the James River. Based on Chesapeake Bay Water Quality Model output, the following nutrient and sediment reduction goals have been established:

- Achieve a 9% sediment reduction from the levels that existed in 1985 for the entire basin by the year 2010.

- For all areas draining directly to the tidal fresh portion of the James, Biological Nutrient Removal (BNR) implementation at point sources and an equivalent reduction in nonpoint sources by 2010. This would result in a 32% nitrogen and 39% phosphorus reduction, based on model simulation, in loading to the river from the levels that existed in 1985. Although the model simulation for this recommendation used a uniform BNR treatment level for all plants discharging to the tidal fresh portion, the overall objective is to achieve the recommended level of reduction in the aggregate point source load. This can be achieved with varying levels of nitrogen and phosphorus removal at the plants, with some operating more stringent treatment than others. This recognizes the varying capabilities and site constraints at the plants, as well as opportunities to cost-effectively enhance treatment where feasible.

- The net nutrient loadings to the lower estuary from all areas should not be allowed to increase and should be capped at 1996 levels. Growth in load coming from areas directly adjacent to the lower estuary should not exceed the reduced load coming from the tidal fresh portion of the river. The resulting zero net increase in loading to the lower estuary will prevent any degradation relative to current water quality conditions.

The living resource improvements associated with the reduction goals as determined by the Chesapeake Bay Water Quality Model are: SAV growth in areas of the tidal fresh James previously identified by VIMS as historic SAV beds, and substantial reductions in chlorophyll levels throughout the estuary. The estimated cost for these improvements is $164 million for point sources and $135 million for nonpoint source BMP implementation.

Two issues will require that the recommended nutrient and sediment reduction goals for the James River be reevaluated in several years:

- The current version of the Chesapeake Bay Watershed Model overpredicts sediment loading in the James River. Future model revisions are likely to correct this.

- The Chesapeake Bay Program is currently working on a process to make the goals required under the Total Maximum Daily Load (TMDL) program consistent with the living resource based goals of the Chesapeake Bay Program.

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I. Background

This document, *Goals for Reducing Nutrients and Sediment in the James River*, was developed as the next step in achieving a comprehensive Tributary Strategy for the James River as required by the Virginia Tributary Strategy Act of 1996. The development of individual tributary strategies for Virginia's southerly tributaries (Rappahannock, York, James, and Small Coastal Basin) stems from a 1992 Chesapeake Bay Program reevaluation which found that nutrient loads from the lower Virginia tributaries contributed little, if any, to the dissolved oxygen deficit in the main Bay. For this reason, Virginia embarked on a two-pronged approach for tributary strategies – a concentrated effort in the Potomac basin to meet a forty percent nutrient reduction goal and expansion of the monitoring and modeling programs in the lower tributaries to help determine appropriate nutrient reduction goals for each river basin.

The <u>Initial James River Basin Tributary Nutrient and Sediment Reduction Strategy</u>, completed in July, 1998, provided information on water quality and living resource habitat conditions, described the actions taken to date to reduce pollutants, and provided an overview of the kinds of additional management actions that could be taken to further restore the health and productivity of the river. The Initial Strategy did not contain restoration goals because key information from the Chesapeake Bay Water Quality Model was not yet available.

The process of developing water quality and living resource goals for the James River has required consideration of a wide range of issues. The goals included in this document were developed to meet the requirements of *Virginia Code § 2.1-51.12:2*, which specifies the content of tributary plans. Goals have been determined for each of Virginia's lower tributaries in order to meet their individual water quality and living resource restoration needs. State staff has worked closely with stakeholders and technical experts to examine the effects of different pollutant reduction scenarios, and to develop goals that will improve the water quality and living resources of the River. By examining the sources of nutrients and sediments, the levels of expected improvements in habitat conditions were predicted for different combinations of pollutant reduction. Each combination of actions was then evaluated against the critical measures of practicality, cost-effectiveness and equity.

In order to provide a forum for stakeholder input to the goal setting process, a James River Technical Review Committee (TRC) was formed. The Committee was composed of representatives from public wastewater treatment facilities, private environmental groups, soil and water conservation districts, industry and local governments. A list of representatives attending TRC meetings is included in Appendix A. The TRC met eight times to consider the results of various Chesapeake Bay Water Quality Model runs as well as other pertinent information. Staff from the Chesapeake Bay Program office of the U. S. Environmental Protection Agency and State Agencies provided technical assistance to the Committee by analyzing and presenting data from model runs, and by synthesizing living resource information.

II. Long Term Vision & Short Term Objectives

The James River TRC, in addition to discussing appropriate nutrient and sediment reduction goals, made broader suggestions for a long term "vision" for the James River and identified shorter term objectives to bring this vision about. It is the hope, that the interaction of many improvements in water quality (increased SAV, nutrient reductions, sediment reductions, oyster replenishments, etc.) will complement each other, resulting in a James River even more rejuvenated than predicted by the mathematical models.

James River "Vision"

An ecologically, aesthetically and economically vibrant river, characterized by:

- All waters meeting the Federal Clean Water Act goals of "fishable and swimmable" with no waters impaired as the result of biological, chemical or physical deterioration due to human activities.
- Restoration of critical shelter and spawning habitat to provide for resurgence and maintenance of numerous ecologically and economically important species of finfish and shellfish [shad, herring, menhaden, oysters, crabs, rockfish, among others]

Improvements in water quality that will allow for:

- Restoration of Submerged Aquatic Vegetation to the maximum extent allowable, and at a minimum, to all historically documented areas.
- Sufficient dissolved oxygen levels to support healthy populations of all indigenous aquatic species.
- Ecologically balanced and sustainable trophic levels throughout the entire food web from primary producers to tertiary consumers.
- Sufficient quality and quantity [flow] of water to meet all designated uses of the river.
- Protection of threatened and endangered species and their habitat.

Achievement of these goals will require support and action from citizens, state agencies and various economic sectors, including:

- Increased public awareness of watershed protection and individual actions that impact the quality of the river.
- Integration of watershed planning into appropriate programs within the state agencies.
- Implementation of more sustainable approaches within the agriculture, forestry and commercial and residential development sectors.

Although we have compiled a wealth of information throughout the development of this Tributary Strategy, continuing work is necessary to improve our scientific understanding in several key areas, including:

- Refining the relationship between nutrient and sediment loadings and their combined affects on algae production and living resources health and habitat.
- Improving our understanding of the large-scale ecological relationships throughout the entire watershed.

Short Term Objectives

The following is a list of objectives designed to move towards the long term James River "vision". Included as bulleted items are some of the possible actions that could be used to meet the objectives.

Restore SAV to the maximum extent allowable, and at a minimum, to all historically documented areas by:

- Identifying areas that could support SAV with improved light penetration;
- Establish test areas to plant SAV;
- Focus nutrient and sediment reduction efforts in areas that historically supported SAV;
- Implement slow-no wake zones in areas that have been identified as likely SAV habitat.

Restore populations of ecologically important species of finfish and shellfish by:

- Removing impediments to anadromous fish migrating upstream to historic spawning grounds;
- Restocking juvenile species until populations are restored;
- Reduce pollution from nutrients, sediment, and toxic chemicals to improve habitat for aquatic resources.

Restore critical populations of living resources in the non-tidal James by:
- Conducting chemical and biological monitoring to identify habitat areas for threatened and endangered species of fish and shellfish;
- Focusing sediment, nutrient, and toxics reduction into those areas identified as critical habitat;
- Ensuring local and state enforcement of erosion and sediment control law and ordinances to reduce sediment loading;
- Increase sediment monitoring on major tributaries to the James to aid in identifying contributing sources and land areas from which the sediment loading is originating.

Improve the understanding of the relationship between water quality and living resources by:
- Initiating research to refine the relationship between sediment and nutrient loads and effects on algae, light penetration and SAV growth;
- Increasing water quality monitoring in the James River to support research into the interrelationship between nutrient and sediment loading, and living resources.
- Studying the historical influence of filter feeding populations on water quality;
- Improving the understanding of sediment transport and re-suspension within the James River.

Meet the Federal Clean Water Act goals of "fishable and swimmable" with no waters impaired as the result of biological, chemical or physical deterioration by:
- Expediting development of Total Maximum Daily Loads (TMDLs) for impaired stream segments;
- Implementing strategies to improve impaired streams and remove them from the 303(d) list;
- Increasing monitoring to identify impaired stream segments;
- Identifying and declaring outstanding national resource waters (Tier III) within the James River watershed to protect them from degradation.

Increase community awareness on a watershed level by:
- Conducting public meetings to inform citizens of the importance of the James River Tributary Strategies and the Chesapeake Bay Program;
- Developing a website for the tributary strategies program;
- Promoting activities such as Adopt-A-Stream, stream bank restoration, and citizen monitoring;
- Focusing educational activities on high priority watersheds with the greatest potential to reduce pollution;
- Educating urban and suburban residents in order to prevent runoff of sediment and fertilizer;
- Encouraging local planning efforts to reduce impervious surfaces, and maintain

natural buffers;
- Providing incentives to communities to conduct watershed planning and to implement strategies to reduce nutrient and sediment pollution.

Enhance nutrient and sediment reduction programs in urban areas by:
- Providing funding for new and innovative management options;
- Developing certification programs for: erosion and sediment control for contractors; urban nutrient management for homeowners; and pesticide and fertilizer use for landscape contractors.
- Funding for local governments that enhance existing programs over state or federal requirements;
- Evaluating the impacts of alternative growth patterns on nutrient and sediment loads, and subsequently on living resources.

Maintain adequate in-stream flow for beneficial uses by:
- Restricting water withdrawals from the James River and its tributaries to maintain flows above the minimum necessary to support aquatic life, recreational uses, and other beneficial uses.
- Avoiding or reducing wetland losses to provide habitat improvements and flood control.

III. Existing Conditions

This section describes the baseline and current annual loading estimates of nitrogen, phosphorus, and sediment entering the tidal portion of the James River. Also presented is a summary of living resource and habitat conditions within the James basin, for key parameters and species that serve as indicators of water quality, including dissolved oxygen, nutrient concentrations, water clarity, submerged aquatic vegetation (SAV), algae, bottom dwelling (benthic) organisms, fish, and shellfish.

Nutrient and Sediment Loads
The Chesapeake Bay Program participants established 1985 as the baseline year, making it the reference point for calculating annual differences in the nutrient and sediment loads. The baseline loads are the sum of 1985 point source discharges and the nonpoint nutrient runoff, associated with 1985 land uses in the James River basin, calculated for an average rainfall year. By accounting over time for process changes and physical upgrades at wastewater treatment plants, and implementation of best management practices to control nonpoint source runoff, estimates have been made of the current loads of nitrogen, phosphorus, and sediment in the James River basin.

Nutrient loads originate from both point sources (municipal and industrial wastewater treatment facilities) and nonpoint sources (agricultural crop and pasture land, and developed urban/suburban land). Virtually all of the sediment loading is associated with nonpoint source runoff, as the point sources contribute a negligible amount by comparison. Sediment input to the James River is a significant issue to be considered in formulating restoration and protection goals, for several reasons:

- the large magnitude of the load (the James has the third highest measured sediment loading of all the Bay tributaries, behind only the Potomac and Susquehanna);
- the impact it can have on water clarity, blocking sunlight needed for growth and survival of SAV, as well as limiting algae growth; and,
- the negative effect it can have on critical habitat in the streambed of the non-tidal, free flowing regions of the James River, west of the fall line.

The 1985 baseline figures for the loads of nutrients and sediment delivered to the tidal James are shown in Table 3.1.

Since 1985, a wide array of nutrient and sediment control actions have been implemented in the James River basin to reduce both the point source and nonpoint source input of these pollutants. The types, locations, and and extent of these control actions were detailed in the *Initial James River Basin Tributary Nutrient and Sediment Reduction Strategy,* a document released by the Commonwealth in July 1998. In general, they include upgrades and improvements made at municipal wastewater treatment plants to control nitrogen and phosphorus discharges, pollution prevention actions taken at industrial facilities, greater use of Best Management Practices (BMPs) by farmers and foresters, improved stormwater management and erosion and sediment control by local governments, and other initiatives.

Table 3.1 – Nutrient and Sediment Loads
James River Basin: 1985

	Point Source	Nonpoint Source	Total	Units
Phosphorus	3.6	2.5	6.1	million lbs/yr

Nitrogen	22.1	19.1	41.2	million lbs/yr
Sediment	N/A	2.01	2.01	million tons/yr

The Chesapeake Bay Program's Watershed Model has been used to calculate the change in controllable nutrient and sediment loads achieved by these activities. Table 3.2 compares the 1985 baseline loads to estimates for 1996, which is the most recent year with land use coverage data available to reflect the implementation of BMPs.

Table 3.2 - Changes in Controllable Nitrogen, Phosphorus and Sediment Loads James River Basin: 1985-1996

	1985 Load			1996 Load (and % change)		
	Point Source	Nonpoint Source	Total	Point Source	Nonpoint Source	Total
Phosphorus (million lbs/yr)	3.6	2.5	6.1	1.5 (-58%)	2.4 (-4%)	3.9 (-36%)
Nitrogen (million lbs/yr)	22.1	19.1	41.2	17.9 (-19%)	18.6 (-3%)	36.5 (-11%)
Sediment (million tons/yr)	N/A	2.01	2.01	----	1.97 (-2%)	1.97 (-2%)

As shown in Table 3.2, between 1985 and 1996, the estimated annual nitrogen load has been reduced about 4.7 million pounds and the estimated annual phosphorus load has been reduced about 2.2 million pounds. This represents an eleven percent annual load reduction for nitrogen, and a thirty-six percent annual load reduction for phosphorus, relative to the 1985 baseline nutrient load. The gross nutrient reductions achieved between 1985 and 1996 were actually greater, but were partially offset by the nutrient-related impacts of growth and development during that eleven year period.

The Chesapeake Bay Program has not yet run the Watershed Model to update the nonpoint source load figures using more recent data on BMP implementation since 1996. This run is expected to be completed by the end of 2000.

- Recently compiled data for the point source facilities indicates that the annual discharged nutrient loads have been reduced even further since 1996. The 1998 point source nitrogen load was approximately 14.4 million pounds per year (a 40% reduction compared to 1985), and the phosphorus load was about 1.39 million pounds per year (a 61% reduction since the baseline year). The notable actions affecting the point source nutrient loads are:

- The phosphate detergent ban went into effect in January 1988.

- Phosphorus control systems (2.0 mg/l, monthly average) installed and now operating at all plants greater than, or equal to, 1.0 MGD discharging to the tidal portion of the river.

- Several industrial plants significantly reduced their nitrogen discharge (e.g., BWXT/ -70%, AlliedSignal-Hopewell/ -81%, Tyson Foods/ -39%).

- Several publicly owned treatment works (POTWs) installed BNR technology: Moores Creek, Falling Creek, Proctors Creek, Henrico, HRSD-VIP, HRSD-Nansemond.

- Other POTWs have made physical and/or operational changes (ammonia control, pretreatment, BNR pilots, upgrades/expansion) significantly reducing their nitrogen discharge (e.g., Lynchburg, Hopewell, South Central Wastewater Authority, Richmond, HRSD-Williamsburg).

- Several significant facilities have gone off-line, with their wastewater now treated at more efficient plants: Smithfield Foods, Smithfield-Gwaltney, Smithfield STP (all now routed to HRSD-Nansemond), and Portsmouth STP (flow diverted to HRSD-VIP).

- These reductions occured despite a 10% increase in the total flow treated, compared to the 1985 flow.

Summary of Living Resource and Habitat Conditions[1]

A long-term monitoring program for the Chesapeake Bay and its tidal tributaries has been in place since 1984 in order to: 1) track long-term trends in water quality and living resource conditions over time; 2) assess current water quality and living resource conditions; and 3) establish linkages between water quality and living resources communities. By tracking long-term trends in water quality and living resources, it can be determined if changes in water quality and living resource conditions have occurred over time and if those changes are a reflection of management practices. Assessments of current status can aid in identifying regions of concern that could benefit from the implementation of pollution abatement or management strategies. By identifying linkages between water quality and living resources it may be possible to determine the impact of water quality management practices on living resource communities.

Monitoring data is collected to characterize water quality in the mainstem James River and its major tributaries (Appomattox, Chickahominy, and Elizabeth Rivers) at a total of 21 stations. The parameters analyzed are total nitrogen, dissolved inorganic nitrogen, total phosphorus, dissolved inorganic phosphorus, chlorophyll *a*, total suspended solids, secchi depth, and bottom dissolved oxygen. Plankton, zooplankton, and benthos (bottom dwelling organisms) make up the living resource component of the monitoring program, with plankton/zooplankton measured at 4 stations, and benthos sampled at 6 fixed and 25 random stations per year. Findings are reported for regions of the tidal James designated by salinity (Upper = tidal fresh/ 0-0.5 ppt; Middle = oligohaline/ 0.5-5 ppt; Lower = mesohaline/ 5-18 ppt).

The "status" of water quality conditions is based on analysis of the most recent 3-year period of record, compared to the *poor* and *good* extremes of the first 12 years of the entire water quality data set for each salinity regime throughout the entire Bay. Values in the lowest third of the dataset were classified as *poor*, those in the middle third were classified as *fair,* and values in the upper third were classified as *good*. The "trends" are statistically derived from the entire period of record, indicating long-term changes (positive, negative, or none detected) for each water quality parameter. Characterization of living resource conditions is based on "indices of biological integrity" (e.g., abundance and total biomass) and productivity.

From the foregoing descriptions, it can be seen that the status of water quality and living resource indicators in the James basin are <u>relative values</u>, being compared to other regions throughout the Bay with similar salinity. Thus, use

[1]Source for this section: <u>Status and Trends in Water Quality and Living Resources in the Virginia Chesapeake Bay: 1985 -1997</u>, Dauer, et. al., AMRL Technical Report No. 3090, September 1998.

of the term *good, fair,* or *poor* is not an absolute evaluation of status but rather a statement relative to other areas of a system that is pervasively stressed by nutrient over-enrichment and high sediment loadings. If these status evaluations compared current nutrient and sediment pollution levels of the James to those found in the James 100 years ago, or to current status of other less impacted estuaries, most statements regarding status would likely use the term *poor*.

Before going into any detail on conditions in the James, there are several summary points that can be made about nutrient and sediment inputs, and the water quality and habitat status. These points framed the goal-setting discussions and decision making undertaken by a Technical Review Committee, which included stakeholder representatives from the basin's four strategy planning regions, in forming their recommendations for consideration by the Secretary of Natural Resources.

- The ratio of point source nutrient loads to nonpoint source loads is greater in the James than in other Virginia tributaries. The relative contribution of nutrients from point sources compared to nonpoint sources has been shifting somewhat over the last decade, as control actions and plant improvements have come on-line (i.e., nonpoint sources becoming a larger fraction of the total load, although the total load is being reduced).
- Sediment inputs are almost exclusively a nonpoint source issue.
- Fall-line nutrient loads are improving.
- Algal levels are elevated in many sections of the tidal river, and seasonal peaks are among the highest in entire Bay drainage.
- Below fall-line improvements in algal levels, total nitrogen and algal growth rates.
- Potential light limitations of algal growth rate exist throughout the river.
- Improving trends in phytoplankton and zooplankton communities in upper James River (tidal freshwater section from fall line to the Chickahominy).
- Deteriorating trend in zooplankton community in the lower James River (more saline section near Hampton Roads and river mouth).
- No trends in the benthic community conditions. Health of the benthos is the best in the Chesapeake Bay region, but this is in relation to other impacted areas -- not compared to a pristine area.
- Concern for potential underwater grass recovery due to poor water clarity.
- Proximity to oceanic water and hydrodynamic mixing prevents dissolved oxygen problems. Lower oxygen conditions only observed in the Elizabeth River system.

1. James River Water Quality and Living Resource *Status* Assessments

a) Nitrogen

- Status of surface and bottom total nitrogen and dissolved inorganic nitrogen was good in all portions of the James River.
- No change in status since 1996.

b) Phosphorus

- Status of surface and bottom total phosphorus and dissolved inorganic phosphorus was good in majority of regions in the James River. Status of surface total phosphorus was fair in the Lower James River (JMSMH) and the James River mouth (JMSPH). Status of bottom total phosphorus was fair in the Middle James River (JMSOH), Lower James River (JMSMH) and the James River mouth (JMSPH). Status of surface dissolved inorganic phosphorus was fair in the Lower James River. Status of bottom dissolved inorganic phosphorus was fair in the

Upper James River (JMSTF) and the Lower James River (JMSMH)[2].
- No change in status since 1996.

c) Chlorophyll *a*
- Status of surface and bottom chlorophyll *a* was good in all portions of the James River.
- No change in status since 1996.

d) Suspended solids
- Status of surface and bottom total suspended solids ranged from fair to good in all portions of the James River.
- Status of surface total suspended solids in the Appomattox River (APPTF) and Upper James (JMSTF) improved from fair to good since 1996.

e) Water clarity
- Status of secchi depth ranged from fair in the upper James River (JMSTF) and the Chickahominy River (CRRMH) to poor in all other regions.
- Little change in status of secchi depth except that Chickahominy went from poor to fair since 1996.

f) Dissolved oxygen
- Status of bottom dissolved oxygen was good in all portions of the James River.
- No change in status since 1996.

g) Phytoplankton
- Status based on the phytoplankton IBI was good at all stations in the James River except TF5.5 where it was fair.
- Status of C^{14} productivity was good at all stations in the James River except LE5.5 where it was fair.
- No change in status since 1996.

h) Zooplankton
- Status of zooplankton communities at station TF5.5 in the Upper James was below minimal.
- Status of zooplankton communities at station RET5.2 in the Middle James was minimal.
- Status of zooplankton communities at station LE5.5 in the Lower James was below minimal.
- Status changed at station RET5.2 from optimal in 1996 to minimal in 1997.

i) Benthos
- Two stations were classified as marginal in status based upon the B-IBI (RET5.2

[2] JMSTF = James Tidal Fresh; JMSOH = James Oligohaline; JMSMH = James Mesohaline; JMSPH = James Polyhaline

and LE5.1).

- Two stations were classified as meeting goals based upon the B-IBI (LE5.2 and LE5.4).
- All B-IBI metrics at all stations had a status that met goals.
- Based upon the random sampling event, the percentage of benthic bottom meeting goals was 54 %, compared to 79% in 1996.
- The 1997 B-IBI categories were 21% severely degraded (< 2.0), 21 % degraded (2.0-2.6), 4% marginal (2.6-3.0) and 54% meeting goals (> 3.0).
- Compared to the 1994-1996 status, RET5.2 changed from degraded to marginal. The status for the other stations was unchanged.
- The major difference comparing the percentages of bottom conditions between 1996 and 1997 was an increase from 0% severely degraded bottom (B-IBI < 2.0) to 21 % in 1997.

2. James River Water Quality and Living Resource *Trend* Analyses

a) Nitrogen

- Improving trends in surface total nitrogen were detected in all segments in the James River except the River mouth (JMSPH).
- Improving trends in bottom total nitrogen were detected in all segments in the James River except the Chickahominy River (CHKOH).
- Improving trends in surface dissolved inorganic nitrogen were detected in the Upper James River (JMSTF) the Middle James River (JMSOH) and the Lower James River (JMSMH).
- Improving trends in bottom dissolved inorganic nitrogen were detected in all segments except the Appomattox River (APPTF) and the Chickahominy River (CHKOH).
- There were no degrading trends in any nitrogen parameters in the James River.

b) Phosphorus

- Improving trends in surface total phosphorus were detected in the Upper James River (JMSTF), the Appomattox River (APPTF), the Lower James River (JMSMH) and the river mouth (JMSPH). Through 1996, improving trends in surface total phosphorus were limited to two station-specific decreasing trends in the Upper James River and a seasonal decreasing trend in the Lower James River (JMSMH).
- Improving trends in bottom total phosphorus were detected in the Upper James River (JMSTF), the Appomattox River (APPTF) and the James River Mouth (JMSPH).
- A degrading trend in bottom total phosphorus was detected in the Middle James River (JMSOH).
- Improving trends in surface dissolved inorganic phosphorus were detected at three stations in the Upper James River (JMSTF). Through 1996, two station-specific decreasing trends in surface dissolved inorganic phosphorus were detected in the Upper James River (JMSTF).

- Improving trends in bottom dissolved inorganic phosphorus were detected in the Upper James River (JMSTF) and the Appomattox River (APPTF).
- There were no degrading trends in surface total phosphorus and surface dissolved inorganic phosphorus in data collected through 1997. Degrading trends in surface total phosphorus were detected in the data collected through 1996 in the Middle and Lower James River but these trends disappeared or reversed direction after the addition of the 1997 data.

c) Chlorophyll *a*

- Improving trends in surface chlorophyll *a* were limited to a decreasing overall trend in the Appomattox River (APPTF) and a single season specific decreasing trend at the river mouth (JMSPH).
- Degrading trends in surface chlorophyll *a* were limited to two season specific trends at the river mouth (JMSPH).

d) Suspended solids

- There were no improving trends in surface total suspended solids in the James River data collected through 1997.
- Degrading station and season specific trends in surface total suspended solids were detected in the Upper James River (JMSTF) and the Lower James River (JMSMH), respectively, in data collected through 1996. These two trends disappeared after the addition of the 1997 data.
- There were no trends in bottom total suspended solids in the James River data collected through 1997.

e) Water clarity

- There were no improving trends in secchi depth in the James River.
- There was a single overall degrading trend in secchi depth at the James River mouth (JMSPH).
- A station specific improving trend in secchi depth in the Upper James and a degrading trend in the Middle James detected in the data collected through 1996 disappeared after the addition of the 1997 data.

f) Dissolved oxygen

- Improving trends in bottom dissolved oxygen were limited to a station specific increasing trend at the James River mouth (JMSPH) and an overall increasing trend in the Upper James River (JMSTF).
- There were no degrading trends in bottom dissolved oxygen in the James River.
- In general, there were no changes in trend analysis results between 1996 and 1997 for this parameter.

g) Phytoplankton

- Improving trends were detected above the pycnocline at station TF5.5 in the Upper James in total abundance, chlorophyte abundance and biomass, cyanobacteria biomass, and picoplankton abundance and biomass.
- Improving trends were detected below the pycnocline at station TF5.5 in the Upper James in total abundance, chlorophyte abundance and biomass, dinoflagellate abundance and biomass (season specific), cyanobacteria biomass,

and bloom producer abundance.

- A degrading trend was detected below the pycnocline at station TF5.5 in the Upper James in Margalef diversity.
- Degrading trends were detected below the pycnocline at station TF5.5 in the Upper James in dinoflagellate abundance (season specific) and Margalef diversity.
- Improving trends were detected above the pycnocline at station RET5.2 in the Middle James in total abundance, dinoflagellate abundance, chlorophyte abundance and biomass, cyanobacteria biomass, and picoplankton abundance and biomass.
- Improving trends were detected below the pycnocline at station RET5.2 in the Middle James in total abundance, diatom biomass, chlorophyte abundance and biomass, cyanobacteria biomass, and picoplankton abundance and biomass.
- A degrading trend was detected below the pycnocline at station RET5.2 in the Middle James in cyanobacteria abundance.
- Improving trends were detected above the pycnocline at station LE5.5 in the Lower James in total abundance, diatom abundance (season specific) and biomass, chlorophyte abundance and biomass, and picoplankton abundance and biomass.
- Degrading trends were detected above the pycnocline at station LE5.5 in the Lower James in cyanobacteria abundance (season specific), Margalef diversity, and bloom producer abundance (season specific) and biomass.
- Improving trends were detected below the pycnocline at station LE5.5 in the Lower James in total abundance, diatom abundance and biomass, chlorophyte abundance and biomass and picoplankton abundance and biomass.
- Degrading trends were detected below the pycnocline at station LE5.5 in the Lower James in dinoflagellate abundance and biomass, bloom producer abundance and biomass, and toxic species abundance.

h) Zooplankton

- Degrading trends were detected at station TF5.5 in the Upper James in all measures of mesozooplankton diversity.
- Degrading trends were detected at station LE5.5 in the Lower James in all measures of mesozooplankton diversity except evenness.
- A degrading trend was detected at station LE5.5 in the Lower James in total mesozooplankton abundance largely as a result of reductions in holoplanktonic organisms including but not limited to calanoid copepods and cladocerans.
- A decreasing trend was detected at station LE5.5 in the Lower James in tintinnid abundance.
- The trend at station TF5.5 in the Upper James in Margalef's diversity changed from an improving trend in 1996 to a degrading trend in 1997.

i) Benthos

- There was a single improving trend in the B-IBI at station RET5.2.
- There were no deteriorating trends in any of the B-IBI metrics.
- There were no trends in the B-IBI through 1996.

<u>3. Elizabeth River Water Quality and Living Resource *Status* Assessments</u>

a) Nitrogen

- Status of surface and bottom total nitrogen was fair in most regions in the Elizabeth River.
- Status of surface and bottom dissolved nitrogen was poor in the Southern Branch (SBEMH) , good in the mainstem of the Elizabeth River (ELIMH) and fair in all other segments.

b) Phosphorus

- Status of surface and bottom phosphorus was fair in all segments of the Elizabeth River except in the Western Branch (WBEMH) where status in surface total phosphorus was poor.
- Status of surface dissolved inorganic phosphorus ranged from poor in the Western Branch (WBEMH) to good in the mainstem of the Elizabeth River (ELIMH).
- Status of bottom dissolved inorganic phosphorus was poor in the Southern Branch (SBEMH), fair in the Eastern Branch (EBEMH) and mouth of the Elizabeth River (ELIPH), and good in the Western Branch (WBEMH) and mainstem of the Elizabeth River (ELIMH).

c) Chlorophyll *a*

- Status of surface and bottom chlorophyll *a* was fair to good in all segments of the Elizabeth River.

d) Suspended solids

- Status of surface and bottom total suspended solids was fair to good in all segments of the Elizabeth River.

e) Water clarity

- Status of secchi depth was poor in all segments of the Elizabeth River.

f) Dissolved oxygen

- Status of bottom dissolved oxygen was good in the Western Branch (WBEMH) and Eastern Branch (EBEMH) and fair in all other segments.

g) Phytoplankton

- Status based on the phytoplankton IBI was good.
- Status of C^{14} productivity was good.
- There was no change in status from 1996 to 1997.

h) Zooplankton

- Status of zooplankton communities at station SBE5 in the Upper James was poor.
- There was no change in status from 1996 to 1997.

i) Benthos

- Both stations were classified as degraded in status based upon the B-IBI.
- B-IBI metrics for community composition generally had a degraded status.
- There was no change in status from 1996 to 1997.

4. Elizabeth River Water Quality and Living Resource *Trend* Analyses

a) Nitrogen

- Improving trends in surface and bottom total nitrogen were detected in the

Western Branch (WBEMH) and Southern Branch (SBEMH) and Elizabeth River Mouth (ELIPH).

- Improving trends in surface and bottom dissolved inorganic nitrogen were detected in all segments in the Elizabeth River except surface dissolved inorganic nitrogen in the Western Branch (WBEMH).

b) Phosphorus

- Improving trends in surface and bottom total phosphorus were detected in all segments in the Elizabeth River except bottom total phosphorus in the mouth of the Elizabeth River (ELIPH).
- Improving trends in surface dissolved inorganic phosphorus were detected in the Eastern Branch (EBEMH) and Southern Branch (SBEMH) and mainstem (ELIMH) of the Elizabeth River.
- Improving trends in surface dissolved inorganic phosphorus were detected in the Eastern Branch (EBEMH) and Southern Branch (SBEMH) and the Western Branch (WBEMH) of the Elizabeth River.

c) Chlorophyll *a*

- There were no trends in surface or bottom chlorophyll *a*.

d) Suspended solids

- There was a single overall degrading trend in surface total suspended solids in the Eastern Branch (EBEMH) of the Elizabeth River.
- Improving trends in bottom total suspended solids were detected Eastern Branch (EBEMH), Southern Branch (SBEMH) and Western Branch (WBEMH) of the Elizabeth River.

e) Water clarity

- There were no trends in secchi depth.

f) Dissolved oxygen

- Improving trends in bottom dissolved oxygen were detected in the Western Branch (WBEMH), Eastern Branch (EBEMH) and Southern Branch (SBEMH) and mainstem (ELIMH) of the Elizabeth River.
- There were no degrading trends in bottom dissolved oxygen in the Elizabeth River.

g) Phytoplankton

- Improving trends were detected above the pycnocline at station SBE5 in the Southern Branch in diatom abundance and biomass, chlorophyte abundance and biomass and picoplankton abundance and biomass.
- Degrading trends were detected above the pycnocline at station SBE5 in the Southern Branch in bloom producer abundance and biomass.
- Improving trends were detected below the pycnocline at station SBE5 in the Southern Branch in diatom abundance and biomass, chlorophyte abundance and biomass and picoplankton abundance and biomass.
- Degrading trends were detected below the pycnocline at station SBE5 in the Southern Branch in cyanobacteria abundance and biomass (season specific),

Margalef diversity, and bloom producer abundance and biomass.

h) Zooplankton

- Degrading trends were detected at station SBE5 in the Southern Branch in all measures of mesozooplankton diversity.
- A decreasing trend in total microzooplankton abundance due primarily to reductions in oligotrich abundance was detected at station SBE5 in the Southern Branch.

i) Benthos

- There was an improving trend in the B-IBI at station SBE5. This same trend occurred through 1996.
- There were improving trends in community composition at both stations (increasing amounts of pollution sensitive taxa and decreasing amounts of pollution indicative taxa).
- There was a improving trend in species diversity at SBE5.

Submerged Aquatic Vegetation[3]

Submerged aquatic vegetation (SAV), or underwater grass, is an extremely important component of the habitat found in Chesapeake Bay and its tidal tributaries. One of the major factors contributing to the high productivity of the Bay has been the historical abundance of more than twenty freshwater and marine species of rooted, aquatic plants. SAV provides food for waterfowl and is critical habitat for shellfish and finfish, especially during their early life stages when protection from predators is crucial to their survival. SAV also affects nutrient cycling, sediment stability, and water clarity. Unfortunately, a systemwide decline of all SAV species in the Bay began in the late 1960s and early 1970s. This decline was related to increasing amounts of nutrients and sediments in the Bay, resulting from development of the Bay's shoreline and surrounding watershed.

In 1989 the Chesapeake Bay Program's Executive Council adopted a policy for the restoration and protection of SAV. This policy highlighted the importance of developing scientifically based SAV habitat criteria (available light, total suspended solids, chlorophyll a, dissolved inorganic nitrogen and phosphorus, growing season), as well as the need for baywide restoration goals in terms of distribution, density, and species diversity.

In 1990 a set of tiered goals were established for the distribution of SAV throughout the Bay and its tidal tributaries. Tier I sought restoration to areas currently or previously inhabited by SAV, as mapped through regional and baywide aerial surveys from 1971 to 1990. Tier II called for reestablishment of SAV in shallow water regions with suitable habitat, out to a depth of one meter, and Tier III extended this boundary out to the 2 meter contour. At the time these goals were set, the baywide acreage of SAV was estimated to cover about 53% of the Tier I target, but only 10% of the Tier III goal.

In the James River basin (including the small coastal basins near the mouth of the James), survey data from 1997 indicated that, in relation to the Tier I goals, 23% of the goal was covered by SAV in the Lynnhaven area; the acreage in the lower, saline portion of the James reached 477% of its goal; and, 0% of the goal was met for the middle James region (Chickahominy). As impressive as the number appears for the lower James, it is important to note that the Tier I target acreage for the entire tidal portion of the river is extremely low -- only 264 acres. By contrast, the Mobjack Bay region near the mouth of the York River has a Tier I goal of about 11,000 acres. Further,

[3]References used for this section are Chesapeake Bay SAV Habitat Requirements and Restoration Targets: A Technical Synthesis, (Batiuk, et al.; USEPA; 12/92), and Analysis of Historical Distribution of SAV in the James River, (Moore, et al.; VIMS; 4/99).

there is no Tier I SAV goal for the tidal freshwater section of the James because the historical (pre-1971) extent of SAV in that region was unknown when the goals were established.

In order to fill in the information gap about the previous existence of SAV in the shallow water regions throughout the James, especially in the tidal freshwater section from Richmond to the Chickahominy, a study was conducted in 1998 by researchers from the Virginia Institute of Marine Science. This study examined the historical distribution of SAV in the James River starting approximately 60 years ago, when aerial photographic surveys first became available. The specific objectives of this study included:

1) To search photoarchives for imagery of the littoral zones in the tidal portions of the James River for evidence of SAV.
2) To delineate and map the changing SAV distributions in these regions at 10 to 20 year intervals, dependent upon image availability.
3) To develop a preliminary evaluation of the currently reported SAV distribution relative to the historical distribution using ground surveys.
4) To display and quantify the SAV distributions using a computer-based geographic information system (GIS) and to summarize the results in report form.

Analyses of historical photography and ground surveys dating from the 1930s indicate that a total of approximately 4,060 acres of SAV were present in shallow water regions throughout the James River. This compares to 190 acres of vegetation reported in 1997 and a James River Tier I SAV restoration goal of 264 acres (areas mapped with SAV from 1971-1991). More specifically, the study determined that the 1930's distribution of SAV in the freshwater and low salinity regions was about 2,355 acres within the James River and Appomatox River Tidal Fresh (JMSTF and APPTF) Chesapeake Bay Program segments. Table 3.3 presents complete results from the study.

Table 3.3. James River SAV abundance. Historical Area (VIMS study); Tier I Goal (Batiuk et al. 1992); 1997 Mapped Distribution (Orth et al. 1998); nd - not determined.

CBP Segment	Historical Area (1937 - 1991) (acres)	Tier I Goal (acres)	1997 Mapped Distribution (acres)
James River Tidal Fresh (JMSTF)	1,970	0	0
Appomattox Tidal Fresh (APPTF)	385	0	0
James River Mesohaline (JMSMH)	724	0	3
Chickahominy Oligohaline (CHKOH)	224	224	nd
James River Polyhaline (JMSPH)	758	40	187
Totals	4,061	264	190

Overall, the temporal and spatial patterns of SAV loss in the James River suggest declines occurred first in the tidal freshwater regions of the upper James beginning approximately 50 years ago, and then subsequently in the lower James beginning about 30 years ago. Since then regrowth has been limited to high salinity areas near the river's mouth along the shoreline of Hampton and Newport News, and an apparent increase in the vicinity of the Chickahominy River. In a series of surveys by boat during the summer of 1998, numerous beds of SAV, many too small to map with high altitude aerial photography, were found in a number of the tidal tributary creeks of the James including the Chickahominy River, Wards Creek, Upper Chippokes Creek, Grays Creek, and Lower Chippokes Creek, as well as along the Hampton-Newport News shoreline. These observations suggest that water quality and other habitat conditions in these areas may serve as useful criteria for achieving the goal of restoration of SAV to its historical distribution levels.

The SAV currently in the river system was found to be dominated by three species. SAV in the tidal freshwater tributaries of the upper James consists principally of *Ceratophyllum demersum* (coontail) and *Najas minor* (common naiad). Here the SAV was growing to depths of 0.5-1.5 meters. The SAV in the high salinity region is the saltwater tolerant species *Zostera marina* (eelgrass). Water depths of the areas currently vegetated with eelgrass were found to be approximately 0.5 to 1.0 meters at mean low water, while historical photographs suggest that vegetation in the lower James formerly grew to depths of nearly 2.0 meters.
Approximately 225 acres of SAV were found to be historically present in the Oligohaline Chickahominy segment (CHKOH). This area measurement came primarily from an aerial mapping survey conducted in this region by VIMS in 1978. The ground survey conducted for the current study in 1998 suggests that the SAV may have increased in abundance in the Chickahominy compared to 1978. Preliminary analysis of aerial photography that was taken of this segment by VIMS in the summer of 1998 confirms these observation and a four-fold increase in area (506 acres) has been estimated (Orth et al. unpubl.).

Finally, because few high salinity SAV beds were present in the James River Polyhaline segment (JMSPH) during the period for which the Tier 1 restoration goals were established (1971-1990), a goal of only 40 acres was selected. Recent regrowth has exceeded this goal. However, it is apparent from the VIMS study's comprehensive analysis of historical SAV distribution in this segment that recovery of SAV is still short of the historical abundance of 758 acres.

The VIMS study results are important to the tributary strategy goal-setting process for the James River, because they give insight about the potential for habitat improvement that was not considered when the Bay Program's SAV restoration targets were adopted. The documented presence of SAV in the low salinity section of the river supports the reasonable expectation that SAV can regrow and survive in larger areas of the tidal freshwater region, given the proper water quality conditions. Further, these reestablished grass beds can provide the stock needed for SAV to propagate throughout the region, and VIMS researchers have observed plant material being transported out of the smaller tributaries into the mainstem James. For these reasons, along with the potential for reductions in chlorophyll concentrations discussed elsewhere in this document, the focus on James River restoration under the tributary strategy should be on SAV reestablishment, with an emphasis on the tidal freshwater region.

IV. Model Results

A primary purpose of water quality modeling is scenario analysis. Models are used to develop and test various management options or strategies aimed at improving water quality. This section of the report focuses on what scenarios were run in order to assess anticipated water quality and living resource responses in the James River below the fall line to various loading scenarios. All scenarios are based on a 10-year simulation period using the corresponding hydrology from the years 1985 to 1994.

Scenario Descriptions
The Chesapeake Bay estuary Model Package (CBEMP) framework provided projections of the expected water quality responses in the tidal James River under a variety of management options. Four reference scenarios provided a base for the analysis (Table 4.1). These scenarios were:

Table 4.1 Reference Scenarios:

SCENARIO	DESCRIPTION
Base Case	1985 land use, 1985 point source discharge & 1985 BMP levels throughout the entire watershed.
1996 Progress	1996 land use, 1996 point source discharge & 1996 BMP levels throughout the entire watershed.
Full Voluntary Program Implementation (FVPI)	Full voluntary program implementation throughout the entire watershed. Point source concentrations of 5.5 mg/L TN and 0.5 mg/L TP with flows projected to 2000. NPS-Ag @ 75% cropland conservation till, 25% conventional till, 10% forest buffers, BMPs to animal wastes (80%), streambank protection (15%), nutrient management (75%), & septic connections (50%).
Limit of Technology	*Limit of Technology* describes the maximum practical level of implementation given unlimited resources and 100% land application based on "do everything, everywhere" using current available technologies throughout the entire watershed. Point source conc. of 3.0 mg/L-TN and 0.075 mg/L-TP with flows projected to 2000. NPS-Ag @ 75% cropland conservation till, full forest buffers, 100% BMPs to animal wastes, streambank protection, nutrient management, & septic connections.

This range of scenarios covered the nutrient and sediment loads from a year prior to Chesapeake Bay Program nutrient reductions (1985 Baseline) to an estimate of the recent loads in the lower Virginia tributaries (1996 Progress), to the maximum level of nutrient/sediment control under a voluntary program (FVPI), to the maximum level of control using currently available technologies (Limit of Technology).

More specific management actions directed toward the lower Virginia tributaries were conducted through a series of five ranging scenarios (Table 4.2). These scenarios were run by changing load conditions in the lower tributaries while the loads from the Potomac and basins above were kept at 2000 Bay Agreement Cap loads. Comparing these scenarios with the equivalent Baywide scenarios allowed for changes in the water quality conditions brought about by nutrient and sediment reductions within the lower tributaries as compared to reductions made elsewhere.

Table 4.2 Ranging Scenarios

SCENARIO	DESCRIPTION
VA 1996 Progress /Trib. Strat Above	Virginia's lower tributaries at 1996 levels for PS & NPS run 10 years using 1985-94 flows. *Tributary Strategy* nutrient reductions applied in the Potomac and above.

BNR + Equivalent /Trib. Strat. Above	Virginia's lower tributaries at BNR for PS everywhere (except the Rappahannock with BNR only applied to facilities>1mgd only) PS concentrations of 8.0 mg/L-TN and 2.0 mg/L-TP, with flows projected to 2000; NPS reduction equivalent on a percentage basis. Sediment reduced by amount equal to NPS phosphorus percent reduction. *Tributary Strategy* nutrient reductions applied in the Potomac and above.
Midpoint 1996-Full Vol. Impl. / Trib. Strat. Above	Nutrient reductions midway between 1996 and full voluntary implementation: Reductions vary by basin (see summary tables). *Tributary Strategy* nutrient reductions applied in the Potomac and above.
VA Interim Bay Agree. / Trib. Strat. Above	Virginia's lower tributaries at an interim 40% nutrient reduction run for 10 years using 1985-94 flows. *Tributary Strategy* nutrient reductions applied in the Potomac and above.
Full Voluntary Implementation / Trib. Strat. Above	Virginia's lower tributaries at full voluntary implementation. Point source concentrations of 5.5 mg/L-TN and 0.5 mg/L-TP, with flows projected to 2000.NPS-Ag @ 75% cropland conservation till, 25% conventional till, 10% forest buffers, BMPs to animal wastes (80%), streambank protection (15%), nutrient management (75%), & septic connections (50%). The program is run 10 years using 1985-94 flows. *Tributary Strategy* nutrient reductions applied in the Potomac and above.

The final series of scenarios were directed toward refining and understanding the living resource responses in the James River based on specific loading reductions (Table 4.3). Many of these reduction scenarios were run at the request of the TRC after review of the scenarios previously described. Sediment reduction-only scenarios were made to determine the response in the estuary without nutrient reduction. A nitrogen and sediment reductions-only scenario was run to determine if nitrogen or phosphorus is the limiting nutrient in the tidal fresh portion of the James. A scenario was also run to determine if nutrient reductions from the areas directly adjacent to the tidal fresh portion of the river had more significance in terms of water quality response than reductions above the fall line. During these runs loads from the Potomac River and tributaries to the north were held constant at agreed upon tributary strategy levels and the Rappahannock and York Rivers, and the Eastern Coastal basins were held at 1996 Progress levels.

Table 4.3 Geographic Management Scenarios

SCENARIO	DESCRIPTION
VA LOT Sediment /Trib. Strat. Above	Virginia's lower tributaries at LOT for total suspended solids (about 33% reduction from base), but use 1996 nutrient loads for PS, NPS, and air. *Tributary Strategy* nutrient reductions applied in the Potomac and above.
Extreme Sediment /Trib. Strat. Above	Virginia's lower tributaries at 40% reduction of total suspended solids from 1985. Note pristine is about 43%. *Tributary Strategy* nutrient reductions applied in the Potomac and above.
James BNR +Equiv. – Above Fall Line	James Above Fall Line at BNR Equivalent NPS / Appomattox, Below Fall Line James and other Lower VA tributaries at 1996 Progress, and Potomac and above loads to *Tributary Strategy* levels.
James BNR Equiv. – Nitrogen - Tidal Fresh Only	James and Appomattox Above Fall Line and Below fall line James discharging to tidal fresh at BNR Equivalent for Nitrogen only / James at 1996 Progress for Phosphorus and sediment; all other lower VA basin loads to 1996 Progress, and Potomac and above loads to *Tributary Strategy* levels.
James BNR Equiv. Tidal Fresh	James and Appomattox Above Fall Line and Below fall line James discharging to tidal fresh at BNR Equivalent; all other below fall line James and other Lower VA tributaries at 1996 Progress; Potomac and above loads to *Tributary Strategy* levels.

The results for all of the modeling scenarios are shown in Table 4.4 (at end of document). The table includes nitrogen, phosphorus, and sediment reductions for each scenario, in addition to the modeled water quality and living resource response. All percentage reductions and living resource changes are in relation to the 1985 base case scenario. Estimated costs for implementation are also included.

V. Technical Issues and Special Studies

During the meetings of the TRC a number of technical issues were raised pertaining to the relationship of nutrients and sediment loadings in the James River to water quality and living resources. Two special studies were funded to provide information on living resources in the James: one was designed to document the previously known extent of SAV in the tidal James River, and the other was designed to summarize the status of living resources in the James River above the fall line. This chapter of the report summarizes some of the key technical issues that were discussed and also includes information on the studies that were conducted.

Submerged Aquatic Vegetation

Despite high nutrient loadings and concentrations, and often extremely high chlorophyl levels, the James River does not exhibit the typical signs of eutrophication (nutrient over enrichment) that would be expected. Typically, an estuary with high levels of algae and abundant nutrients will exhibit areas of hypoxia (low levels of dissolved oxygen) or anoxic conditions (total lack of dissolved oxygen). While low dissolved oxygen levels have been recorded, the James River does not exhibit the acute or chronic conditions reported in other estuaries. Nevertheless, there are indications that the river is overly enriched. In particular, there is very little submerged aquatic vegetation (SAV) or underwater grasses in the estuary (tidal portions) of the James River.
Recent high level flows of fresh water have brought higher than normal runoff of nutrients and sediments. As a result, underwater grasses decreased bay-wide in 1998. These decreases included declines in SAV in the lower James River estuary. Throughout the bay watershed, SAV covers approximately 63,495 acres (approximately 10% of the area once thought to be covered by SAV). In the James River estuary there were only approximately 44 acres of SAV in 1997 and the majority of the remaining SAV was located in the lower estuary. There is very little SAV evident in the tidal fresh water portion of the river. Despite SAV declines throughout the bay watershed, the lack of SAV in the James River Estuary presents a stark contrast to other river basins in Virginia. For example, recent surveys indicate that there are 11,384 acres of SAV in the York River estuary, and approximately 267 acres of SAV in the Rappahannock River estuary.

SAV is a vital resource that produces oxygen; provides a nursery, food, and protection for a variety of finfish and shellfish; reduces the erosive effect of wave energy; absorbs nutrients and other pollutants; and traps sediments. Therefore, the presence of SAV serves as an important indicator of water quality conditions. SAV abundance and biomass are tied to water quality conditions, the characteristics of the substrate, and hydrologic characteristics of the river. High levels of turbidity and nutrient enrichment can decrease SAV growth and survival. High nutrient and sediment levels decrease water clarity and, therefore, reduce light availability for SAV. In addition, high nutrient concentrations can fuel the growth of algae living on the leaf surfaces of SAV thereby restricting necessary light from reaching the actual plant leaf itself.

SAV health and restoration efforts are closely tied to water quality and, therefore, serve as crucial indicator of the health of the Chesapeake Bay and its tributaries. Due to the direct relationship between SAV and water quality, trends in the distribution and abundance of SAV are very helpful in understanding trends in water quality. As such, low levels of SAV in the James River estuary raise serious concerns about water quality.

While there is much empirical data available regarding previous levels of SAV in the James River, there is sufficient anecdotal information to suggest that there had previously been substantially more SAV in the river. To provide better information regarding historic SAV levels in the James River, the Virginia Institute of Marine Science was commissioned to conduct an analysis of ground surveys and historical photography. Based on an analysis of 1930s surveys and photography, approximately 4060 acres hectares of SAV were identified in shallow water areas throughout the James River. Analysis of available photography from subsequent years indicates a temporal and spacial pattern of loss of SAV in the river. SAV declines first occured in the upper estuary approximately 50 years ago and then subsequently in the lower estuary begining approximately 30 years ago.

As described in Section III of this document, the Water Quality Model provides an indication of how living resources (SAV) are likely to respond to changes in water quality resulting from various implementation scenarios. As shown in Table 4.4, the maximum SAV response is predicted at the current limit of technology. Even at this extremely high level of implementation, SAV is only predicted to increase to 677 acres. With 1996 progress and no further loadings, SAV is predicted to increase to 350. The model predicts the greatest SAV response in the tidal fresh water portion of the river. This area currently has very little SAV but it is considered critical for finfish populations.

Despite the relatively modest increases in SAV predicted by the model scenarios, there are a number of compelling reasons to be hopeful that significant improvements in water quality and the health of living resources (including SAV) can be achieved through the recommended level of implementation.

- The fact that the model is showing some SAV response at the recommended level of implementation is significant given the near absence of SAV in the river (particularly in the tidal fresh water section of the river).
- There are a number of limitations to the model that suggest that an even greater SAV response would likely occur at the recommended level of implementation. In particular, the model does not have a strong feedback mechanism to predict the localized water quality benefits that would result from SAV establishment; the model only estimates SAV growth at the one meter contour level, yet most SAV establishment in the James River could be expected at the half meter level or above; and, the model uses a single species to predict response and that species only responds under fairly favorable conditions. These factors make the model predictions for SAV response very conservative.
- There has been substantial SAV recovery in similar river systems when nutrient levels have been reduced; consequently, the James River is likely to have a similar response to nutrient and sediment reductions.

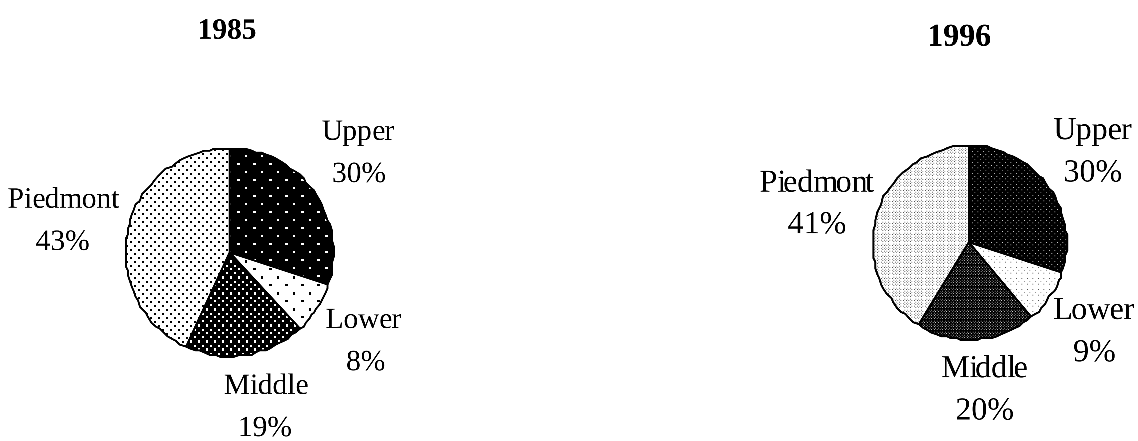
Sediment

Model runs and fall line monitoring results indicate that the delivery of sediment loads to the tidal James River is very high. Suspended sediment prevents light from reaching down into shallow waters to support the growth of submerged aquatic vegetation (SAV). Further, model runs indicate that Best Management Practice (BMP) implementation results in a smaller percentage reduction for sediment in the James basin than in other basins.

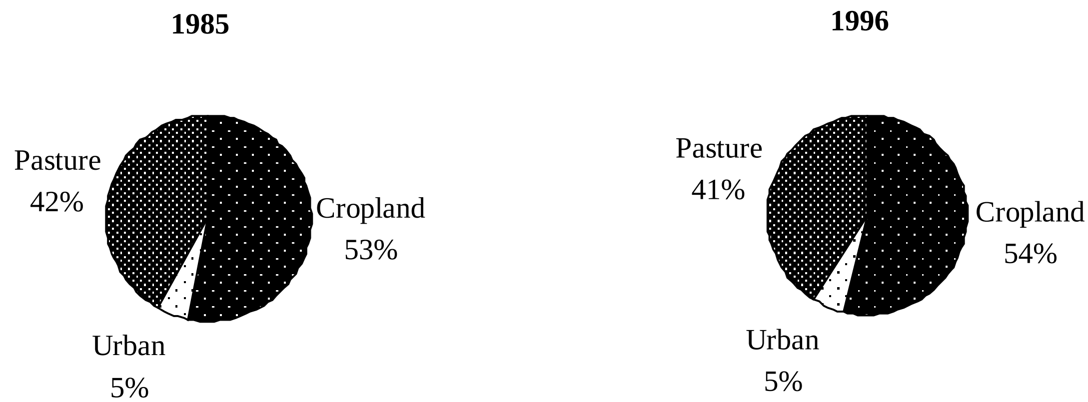
Over seventy percent of the sediment loading to the James River estuary comes from the Piedmont and Upper James regions. This is due to relatively more agricultural land in these regions, steeper slopes, and more highly erodible soils in comparison to the lower areas of the basin. Approximately ninety-five percent of the sediment loading in the basin comes from agricultural land. The loading is fairly evenly split between cropland and pasture. Urban loading has increased slightly from 1985 to 1996 due to increased urbanization, but the overall contribution from urban land in terms of total loading to the estuary is small.

A workshop on sediment loading to the James River basin was convened

Sediment Source by Region



Sediment Load by Source



James River Basin Sediment Loading Review Workshop

A workshop on sediment loading to the James River basin was convened in Fredericksburg, VA on March 23, 1999, to discuss reasons why the sediment loads to the tidal James are so high compared with other Bay tributary basins. Chesapeake Bay Watershed Model sediment loading outputs, James and Appomattox fall line, and nontidal James basin water quality stations sediment loading data, and other relevant geological data were also examined. Workshop participants included scientists from regional academic institutions, U.S. Geological Survey hydrologists and analysts, Chesapeake Bay Program modeling experts, and Virginia agency James Tributary Strategy Team Leaders. The workshop was comprised of four major discussion areas that responded to specific questions, summarized below. Recommendations from the workshop are provided later in this section.

Chesapeake Bay Watershed Model Calibration and Results

Is there something in the watershed model calibration that may be causing excessive sediment loads to the tidal James? How well do watershed model loads and fall line load compare over time at the Cartersville fall line station?

Sediment calibrations for the Chesapeake Bay Watershed Model are generally good to excellent based on accepted empirical calibration ranges, with the exception of the James basin for which sediment calibration was fair. In comparing model simulated loads and loads derived through monitoring data across the full range of river flow conditions, the watershed model under-estimates suspended solids loads at low flows and over-estimates loads at high flows. The scour function included in the model could be reduced to reduce the over-estimation at high flows and high suspended solids concentrations, but there is no technical basis on which to base that change at this time.

How does the Natural Resource Inventory (NRI) estimated erosion rate for the James basin compare with rates from other Bay tributary basins?

There are no significant differences in the NRI rates used in the James basin compared with those applied in other Bay tributary basins.

How does the Bay watershed model estimated erosion rate compare with NRI estimated erosion rates?

Based on a review and comparison for six land uses (forest, high till, low till, pasture, pervious urban, and hay), James watershed model erosion rates are generally within the acceptable range or lower than the NRI estimate erosion rates modified using the universal soil loss equation to reflect the erosion rates from the six different land uses.

James Basin Nontidal and River Input Monitoring Program Findings

What are the patterns in sediment concentration and loads across the nontidal reaches of the James basin and at the fall line?

From the upper reaches of the watershed downstream towards Richmond, the sediment yields increase stepwise, with a large jump between Scottsville and Cartersville and then again between Cartersville and Richmond. This is directly opposite the picture in a less disturbed, more natural river system, where sediment yields should actually decrease as one travels downstream. This is because the cumulative sediment load would be normalized against an ever-increasing watershed acreage. These sediment yield findings indicate that there are large sources of sediment loadings in the watershed areas draining into the James River between Scottsville and Richmond.

No statistically significant trends were observed in suspended solids loads from the James River basin over the past eleven years (1988-1998) after accounting for variations in flow.

How do the James basin fall line loads and sediment yields compare with other Bay tributary basins loads and yields?

The Potomac (156 X 10^7 kg/yr) has the highest sediment loads, followed by the Susquehanna (124 X 10^7 kg/yr), the James (66.9 X 10^7 kg/yr), and then the Rappahannock (44.7 X 10^7 kg/yr). The Rappahannock (964 (lb/acre)/yr) and the Potomac (463 (lb/acre)/yr) had higher sediment yields compared to the James (368 (lb/acre)/yr). The Appomattox had a mean annual load of (1.79 X 10^7 kg/yr) and a mean annual yield of (45.8 (lb/acre)/yr). The mean annual sediment loads and yields at the river input monitoring stations were based on 1988-1998 data.

<u>Insights from James Watershed Geology, Geography</u>

What are the possible causes behind the elevated sediment loadings from the James basin--natural in origin? Something about the soil/geology of the basin? Sediment bed loads? Man-induced?

On large geologic and geographic scales, there are a number of factors/conditions within the James basin that promote higher sediment runoff. The James River is a unique system, particularly in its headwaters. The basin's headwaters are high in elevation; the Piedmont is relatively low elevation, resulting in a relatively steep slope.

In the James basin, the relief (the difference between the maximum and minimum elevations within a specified area) is much greater than basins to the north (i.e., Shenandoah) and south (i.e., New River) within the Valley and Ridge region.

Along the length of the river there is a relatively constant, rather steep slope, which is a unique profile for a major river like the James. This is could be part of the reason behind the increasing sediment yield as one travels downstream from the river's headwaters towards Richmond. The overall geography of the James basin provides a very effective sediment delivery system given that the mainstem James is much lower in elevation than the directly surrounding plateaus. The smaller tributary creeks that flow directly into the mainstem James River form steep sloped gullies draining the surrounding lands.

Over a geological time scale, the James is eroding about four times faster than other Chesapeake Bay tributaries, not only delivering more sediment over time, but also strongly influencing the topography of the James basin.

Because the deforestation, large scale agriculture, and mining of the Valley and Ridge headwaters of the James basin occurred much later than such activities in the Potomac and Susquehanna River basins, sediment loads from these events contributed more recently to sediment bedload along the James.

The James has a much greater proportion of land area in the Piedmont versus the Valley and Ridge physiographic provinces compared to the Potomac and Susquehanna basins, which both have low proportions of their land area in the Piedmont. The underlying soils/substrate in the Piedmont have a much higher tendency to erode, leading to significant sediment runoff and re-distribution to the downstream river valleys during the post-settlement period.

Historical land use patterns have had a strong influence on the current sediment yields from the James basin. Almost all the Piedmont within the James basin was deforested and/or farmed since colonial times. This led to erosion and delivery of sediment to the James River valleys, which are the sediments now being eroded by tributary streams and the river itself and delivered downstream. As the tributary streams and river itself meander within their geologic valleys over time, they will continue to erode these sediments deposited within the river valley from times of greater deforestation.

<u>Sediment Reductions Under management Scenarios</u>

Why are reductions in sediment loads so limited under the full range of management scenarios up to and including Limit of Technology?

The watershed model finding that delivered sediment loads are much higher than the edge of stream loads in the James, due to high degree of scour of stream bed sediments, is supported by the review of geologic and geographic factors contributing to high sediment yields from the James basin. The management practices generally modeled under the range of management scenarios including Limit of Technology do not include stream bank stabilization/stream restoration practices (beyond riparian forest buffers, which are modeled to address overland flow, not streambank erosion). The erosion and delivery of post-settlement fluvial deposits of sediment already contained within the river channel are not affected by the modeled management practices as these practices will have no influence on movement of the stream or river within its defined geological channel.

In the James basin, the watershed model ratio of delivered sediment load to edge of stream load is higher than the other major Bay basins--Potomac, Susquehanna, Patuxent, York, and Rappahannock, supporting the observation that James River sediment load reductions are less responsive to the range of management actions than in other basins for the reasons cited above.

What are the implications for management actions directed towards reducing sediment loads to the tidal James?

The watershed model's over-estimation of the suspended sediment loads at higher concentrations and river flows will have a tendency to dampen or reduce the effectiveness of management practices in reducing sediment loads delivered to the James tidal waters. The James should respond more quickly to the application of management actions given the slope of the basin compared to adjacent tributary basins. Implementation of management actions should, in part, be directed toward restoring riparian forests and stabilizing stream banks within the river valley to the river's edge within the Piedmont region of the James basin. Stream restoration in terms of regrading stream banks decreasing the slope and moving fluvial deposits uplands away from the areas of the stream movement will help prevent erosion of sediments along the river.

Action Items

The following possible action items were identified at the March, 1999, Sediment Loading Review Workshop in Fredericksburg:

1. In the next scheduled upgrade/refinement of the Bay watershed model, further refinements should be made in the James basin sediment calibration by extending the calibration period beyond 1992 to take full advantage of the enhanced storm event monitoring at the Cartersville station initiated in 1989.

2. The proportion of the sediment loads from the different land uses should be examined and compared with other basins to determine if there are outlier loading rates.

3. The sources of NRI data, and whether the locations they were collected from would reflect areas of higher erosion rates along the river, should be examined.

4. The state, local, and federal partners need to put into place comparable sample collection schemes at all water quality monitoring stations upstream of the Cartersville river input station.

Chlorophyll[1]

High chlorophyll "a" concentrations have been reported in the tidal fresh portions of the James River. Chlorophyll levels in the tidal portion of the James River often exceed 30 ug/l in the area near Hopewell. Of 40 tidal systems analyzed worldwide, the James River had some of the highest chlorophyll "a" levels reported (Monbet 1992). The other two estuaries with similar high levels were the Potomac and Patuxent Rivers, both point source dominated rivers. Despite high chlorophyll levels, the James River does not experience the acute periods of depressed oxygen levels in bottom waters that have been documented in the York and Rappahannock Rivers.

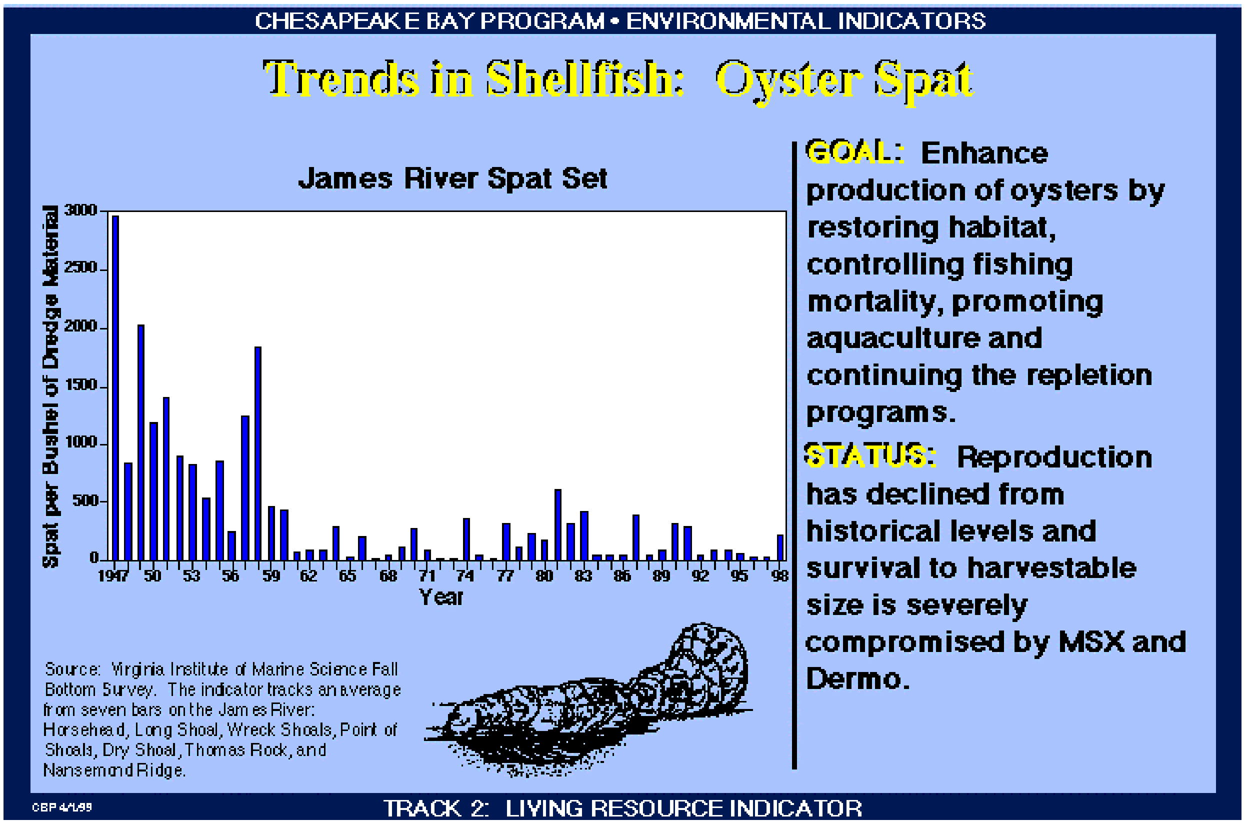
Although high chlorophyll "a" concentrations have been reported in portions of the James River, the impact of chlorophyll reduction in terms of living resource improvements is not clearly understood. The linkages between chlorophyll concentration, optimal plankton composition, and the overall influence of plankton composition on higher trophic levels need to be more clearly established. Without these linkages, the impact of chlorophyll reduction on fisheries and oysters can not be predicted with a high degree of certainty.

Among Virginia's tributaries, algal growth rates (as determined by measuring the rates of primary productivity at phytoplankton monitoring stations) were highest in the James River (Dauer *et al.* 1998). While these rates may be controlled by either available nutrients or the amount of available light, it has been determined that the tidal fresh James River was light limited (Haas and Webb1998; Lung 1986). However, if light limitation was improved through the removal of suspended sediment, there is a substantial supply of nutrients (in the form of inorganic nitrogen) to enhance algal growth thereby increasing chlorophyll levels. In fact, dissolved inorganic nitrogen levels in the James were the highest of any of the Virginia tributaries. This suggests that sediment removal without reductions in dissolved inorganic nitrogen could lead to higher chlorophyll concentrations.

Oysters

At its historic peak, oyster spat production in the James River was ten times as high as production in Maryland. The filtering capabilities of the oyster enable it to remove large quantities of algae and sediment from the water column, while its shells provide habitat for a variety of benthic organisms and fish species. In fact, some scientists feel that oyster restoration is an important key to improving water quality and the overall health of the bay and its tributaries. Historically, oysters were extremely important economically and ecologically. However, due to over harvesting and the diseases MSX and Dermo harvestable oyster populations in the James River and throughout the Chesapeake Bay ecosystem have dropped to their lowest level in history. Despite severe depletion of oyster populations, spat production in the James River continues to be higher than most other rivers. Favorable dissolved oxygen levels and habitat conditions help oysters survive long enough to spawn in the James River. Because oysters are spawning in the James River, there is a strong potential for restoration.

Clearly one of the long-term goals of the James River Tributary Strategy should be to restore this vital natural resource. An important step in this effort will be the establishment of aquatic reefs. Aquatic reefs provide essential habitat for the Bay's oysters, as well as finfish and crabs. Historically, reefs of densely packed individual oysters grew upward and outward, creating hard surface over many acres of bottomland and three-dimensional habitat for finfish and shellfish.



Riverine Living Resources

Many of the water quality goals established for the Chesapeake Bay restoration effort, and by extension, for the tidal portion of the James River, are based on habitat requirements (e.g., dissolved oxygen, nitrogen, and phosphorus levels; light penetration through the water column) for living resources that inhabit the estuarine portion of the Chesapeake Bay ecosystem. Comparatively much less work has been done on habitat requirements and current living resources conditions for the riverine (i.e., freshwater) portions of Chesapeake Bay tributaries. The James River has been extensively studied during the past fifty years by aquatic ecologists and conservation biologists. The Department of Conservation & Recreation funded a recently completed study by scientists at Virginia Commonwealth University (VCU) to:

- survey and synthesize relevant literature and data sources on living resources in the non-tidal portion of the James River;
- describe the ecological roles of the primary species groups inhabiting this area of the river;
- describe the characteristics of the major in-stream and riparian habitats along the river;
- link habitat units to the distribution and ecology of riverine species.

The results of this work (Garman and Smock, 1999) will be valuable to help target nutrient and sediment reductions, and watershed restoration activities, in the James River Basin from the fall line in Richmond to the headwaters. Important findings from the study are summarized below.

<u>Critical Habitat Characteristics</u>

Garman and Smock (1999) identified four habitat zones along the James River upstream from Richmond. The Valley zone lies between the origin of the mainstem James (confluence of the Jackson and Cowpasture Rivers) downstream to the zone of influence of the impoundments above Lynchburg. The zone is distinguished by a well-developed sequence of riffles, runs and pools occurring along its entire length. Water velocity is overall faster here than elsewhere along the river. There is a diversity of depth and water velocity regimes, including all combinations of shallow and deep areas with fast and slower flow, providing a wide variety of habitats for riverine biota. The sediment of the Valley zone consists predominately of large particles, primarily boulders and cobble. This zone also has the greatest amount of large woody debris (i.e., snags) in the channel. The wood occurs primarily along near-bank areas, falling in directly from the riparian area or being deposited there after having been transported from upriver. This wood, ranging in size from limbs and branches to entire mature trees, is an important component of the physical structure of the river for many organisms, many fish often aggregating around the wood and many species of macroinvertebrates and algae living on the wood. The water chemistry of the zone also is distinct from other regions. The conductivity, pH, alkalinity and hardness of the water is higher here than farther downstream, reflecting inputs from tributaries that flow over areas of limestone in the Valley and Ridge physiographic province.

The Impounded zone above Lynchburg lies immediately downstream. Three dams regulate flow from the Balcony Falls Dam at Glasgow to Scotts Mill Dam at Lynchburg. The naturally occurring morphology of riffles and pools is drowned by the impoundments, producing an area with overall greatly increased water depth and much reduced water velocity. The river's sediment though this zone consists primarily of bedrock and large particles that are highly embedded with sand, reflecting the low scouring and increased deposition of sediment that occurs in impounded areas. Overall, the habitat in this zone is far less diverse and conducive to supporting riverine species than in the other zones of the river, although this area does increase the overall habitat diversity occurring along the mainstem of the river.

Garman and Smock termed the reach of river from Lynchburg to Richmond the Piedmont zone. Riffles in this reach generally are not nearly as well-developed or extensive as in the Valley zone. Water velocity through this zone is variable but overall far lower than in the higher gradient areas. A variety of all sizes of sediments are present, including some extensive areas of exposed bedrock. The water chemistry of this zone clearly shows the influence of inputs from tributaries draining areas with predominately crystalline rock. Conductivity, pH, alkalinity and hardness all are lower than in upstream areas. Increases of both point and non-point source inputs to this section of the river also are evident, as indicated by generally higher fecal coliform concentrations and nutrient loading to the river. The water also is not nearly as clear here, transporting a suspended solids load during base flow that on average is double that occurring upriver. Particularly within the Piedmont zone, submergent/emergent aquatic vegetation (SAV), including water willow (*Justica americana*), water stargrass (*Heteranthera dubia*), and *Polygonum* spp., may form extensive beds in areas with low to moderate flow, gravel and cobble substrate, and water 1-2 m in depth. The physical structure represented by beds of freshwater macrophytes is probably an important component of fishery habitat, particularly as a refuge from predators.

At Richmond the river begins its rapid descent through the Fall-line zone to the more sluggish waters of the Coastal Plain. This is an area about 15 km in length where the river drops at a rate of about 2 m/km. Fast flowing water, extensive outcroppings of bedrock, and riffles of well-sorted boulders and cobble characterize the zone. A number of low-head dams cross the channel, with all but Boshers Dam at the head of the Fall-line zone having been recently breached. Deep pools and accumulations of large woody debris are scattered through the area. Together, these characteristics make this the most heterogeneous section of the river, providing a variety of distinct riverine habitats. The water chemistry and quality also differ here from other zones. Chemically, the water has the lowest pH, alkalinity and hardness of any of the sections along the upper mainstem, reflecting continuing inputs from Piedmont tributaries. The effects of urbanization also are evident, water quality being lower here than elsewhere along the upper mainstem. Fecal coliform concentrations, resulting primarily from a large number of combined sewer outfalls that discharge directly to the river during storm events, are more than an order of magnitude higher here than anywhere upriver. Suspended solids concentrations also are high, the water being far more turbid here than upstream.

Several low- to moderate-head dams impound sections of the James River within the Fall-line. The most significant of these – Manchester, Brown's Island, Belle Island and William's dams - are interrupted by natural or constructed breaches. The construction of a vertical slot fish passage at Bosher's dam was completed in Spring, 1999.

<u>Fish</u>

At least 72 fish species have been documented as occurring in the nontidal James River (Garman and Smock, 1999). Several freshwater fish families (minnows, sunfishes, suckers, and darters) contribute greater than 70 percent to the overall species richness (i.e., the total number of species present) in the nontidal James River. Fish species richness tends to be highest in the Piedmont zone, followed by the Valley zone. Certain groups of fish species are characteristic of each of the four river habitat zones. Several fish species are considered to be native to the James River drainage, but only one (stripeback darter) regularly inhabits the mainstem, particularly the Valley zone. Over one-third of the fishes documented in the nontidal James River may be classified as either introduced or possibly introduced. Of the 25 non-native species, many were probably introduced by state and federal fisheries management agencies, according to Garman and Smock. Smallmouth bass, flathead catfish, and blue catfish are well-known species in this group. Four species of anadromous fish (American shad, hickory shad, blueback herring, and alewife) annually migrate from ocean waters to spawn in freshwater tributaries including the James River. The recent completion and operation of the fish passage facility at Bosher's Dam at Richmond's upstream end is intended to allow these species access to spawning areas in the river all the way upstream to Lynchburg.

Algae

Algae, one-celled plants that are common in rivers, are widely represented along the nontidal James River. Algae serve as an important food source for some macroinvertebrates and fish.

Macroinvertebrates

Benthic macroinvertebrates are an important component of the living resources of rivers. They consume benthic algae and, in turn, serve as food for other macroinvertebrates and higher trophic level organisms such as fish. Macroinvertebrates are good indicators of water quality and habitat conditions because they integrate the effects of both short- and long-term environmental changes into responses that can be easily measured.

The James River supports a highly diverse macroinvertebrate community, with at least 132 species having been identified in the mainstem. Common groups that inhabit the river include leeches and aquatic worms, crayfish, aquatic insects (e.g., mayflies, stoneflies, caddisflies), and mollusks (e.g., freshwater clams, mussels, and snails). Only five macroinvertebrate species are abundant along the entire length of the mainstem. There are distinct differences in the macroinvertebrate communities inhabiting each of the four habitat zones. Differences in habitat characteristics, particularly the nature of the bottom substrates, among the zones is the key factor behind the community differences. Only two crayfish species are regularly reported as occurring in the mainstem James River.

Macroinvertebrates vary considerably in their tolerance to pollution and habitat degradation. Analyses of macroinvertebrate abundance and pollution tolerance data by Garman and Smock (1999) suggest that the community in the Valley zone indicates the least degraded conditions, followed by the Piedmont and Impounded zones. The Fall-line zone showed the most degraded conditions in terms of the macroinvertebrate community. Garman and Smock concluded that sediment deposition within the river is degrading bottom habitat and affecting the macroinvertebrate community.

VI. Goal Setting

The James River TRC met eight times but failed to reach consensus on appropriate nutrient and sediment reduction goals for the river. Fundamental differences among committee members could not be resolved on many of the technical issues previously discussed in this document. These include:

- The high cost of nutrient and sediment reduction versus the benefit of relatively small gains in SAV predicted in the model as compared to other basins. Arguments can be made both that the model is likely to overpredict and underpredict actual SAV recovery.

- The level of achievable sediment reduction in the James basin through Best Management Practice implementation. Sediment reduction in the James basin is critical to improving light penetration for SAV growth and yet the watershed model shows that very high levels of implementation are required for even small percentage reductions of sediment in the James.

- The living resources benefit due to algae reduction. The acute dissolved oxygen problems that exist in other estuaries due to elevated algae levels do not exist in the James River.

- The ability to improve water quality in the James River without restoration of the oyster to previous population levels.

The full positions of various TRC members in regards to nutrient and sediment reduction goals are included in Appendix B.

Nutrient and Sediment Reduction Goals

Based on Chesapeake Bay Program Water Quality Model output, goals have been developed for nutrient and sediment reduction in the James River to be achieved by the year 2010. For this discussion, the tidal fresh James refers to the portion of the river from Richmond to the Chickahominy River and the lower tidal portion of the river is from the Chickahominy to the mouth of the James.

Nutrient Goals

For all areas draining directly into the tidal fresh portion of the James River, Biological Nutrient Removal (BNR) implementation at point sources and a proportional nutrient reduction from nonpoint sources. This would result in load reductions of 32% for nitrogen and 39% for phosphorus to the river as compared to 1985.

Model scenarios show that above fall line nutrient reductions have minimal impact on SAV improvement and chlorophyll reduction. The same is true of nutrient reduction in the lower tidal portion of the river. The model also shows that SAV response is optimized with both sediment and nutrient reductions, as opposed to one or the other.

Although the model simulation for this recommendation used a uniform BNR treatment level for all plants discharging to the tidal fresh portion, the overall objective is to achieve the recommended level of reduction in the aggregate point source load. This can be achieved with varying levels of nitrogen and phosphorus removal at the plants, with some operating more stringent treatment than others. This recognizes the varying capabilities and site constraints at the plants, as well as opportunities to cost-effectively enhance treatment where feasible. Owners will be encouraged to collectively meet this nutrient reduction objective, utilizing available cost-share and other market-based incentives.

The net nutrient loadings to the lower estuary from all areas should not be allowed to increase and should be capped at 1996 levels. Growth in load coming from areas directly adjacent to the lower estuary should not exceed the reduced load coming from upstream. The resulting zero net increase in loading to the lower estuary will prevent any degradation relative to current water quality conditions.

Sediment Goals

The sediment reduction goal is a 9% reduction in total sediment loading over the entire basin from the levels that existed in 1985. This goal is equivalent to the reduction achieved under the Full Voluntary Scenario of the Chesapeake Bay Watershed Model.

In order to assist with choosing a level of sediment reduction in the basin that would be difficult to reach and yet still possible in a ten-year period, a number of Soil and Water Conservation Districts in the James basin were asked to project levels of BMP implementation. The exercise assumed that funding and technical assistance were not the limiting factors to implementation. A detailed summary of this projection by BMP is included in Table 6.1.

The planning process that resulted in Table 6.1 focused primarily on agricultural BMPs. The Chesapeake Bay Watershed Model estimates that approximately 95% of the sediment reaching the James estuary is from agricultural sources. However, the Watershed Model is not capable of accurately predicting streambank and shoreline erosion losses. It is possible that streambank and shoreline erosion are also significant sources of sediment to the James estuary, but it is not known to what extent this is a naturally occurring process and to what extent it may be reduced through BMP implementation. The potential for sediment reduction from these sources needs further investigation, and should not be discounted in the development of a final implementation plan for the tributary strategy.

Living Resource Response

The associated living resource response to the recommended reduction goals include SAV growth in areas of the tidal fresh James identified by VIMS from historical survey results as previously sustaining SAV beds, substantial reductions in chlorophyll levels

Table 6.1 at end of document.

throughout the estuary, and improvements in non-tidal freshwater stream habitats. The water quality improvements associated with the recommended goals as predicted by the Chesapeake Bay Program Water Quality Model would be between the James Tidal Fresh BNR Equivalent for Nitrogen Scenario and the Full Voluntary Scenario shown in Table 4.4.

The reduction in algae, nutrients, and sediment in the tidal fresh portion of the river will allow enough light to reach into shallow waters to support the return of underwater grasses. Restoration of grass beds to the upper tidal river will greatly expand existing recreational fishing opportunities for largemouth bass and other tidal fresh sport fish. Once grass beds gain a foothold, they will also begin to improve water quality themselves by stabilizing shorelines, minimizing resuspension of sediments into the water due to wind and waves, and filtering nutrients out of the water.

The reduction in nutrients to reduce the overabundance of algae in the water that exists today in the James River should also support the return of algae species more desirable to fish such as menhaden. This in turn should improve the food available for rockfish and blue fish.

Costs

The estimated costs for these improvements is $164 million for point source BNR implementation and $135 million for nonpoint source BMP implementation. Current cost-share funding available through the Water Quality Improvement Fund will provide 75% of the cost for agricultural BMP implementation and 50% of the cost for BNR implementation and non-agricultural nonpoint source BMPs.

Implementation Plan Development

The next step in the development of a tributary strategy for the James River is the development of an Implementation Plan designed to achieve the nutrient and sediment reduction goals that have been adopted. The development of an implementation plan will be a locally based process that will involve all of the stakeholders in each region. The purpose of the implementation plan is to build on the work that has been done up to this point and to identify specific BMPs that when implemented will attain the reduction goals. Implementation plan development will consider the full range of available BMPs and will be based on practicality, implementability, and cost effectiveness.

Reevaluation of Goals

Two issues will require that the recommended goals for the James River be reevaluated in several years.

Model Overprediction of Sediment

The current version of the Chesapeake Bay Watershed Model overpredicts sediment loading to the fall line of the James River. A version of the model that will correct this problem is under development. It is difficult to predict the consequences a more accurate prediction of sediment loading will have on water quality response in the estuary. More accurate delivery of sediment to the fall line may require that additional shoreline erosion within the estuary be included in the model in order to match monitoring data in the estuary for total suspended solids. It is likely that the changes to the Watershed Model model will result in the need to also recalibrate the Water Quality Model. A timeline for completing this work has not yet been established by the Chesapeake Bay Program.

Adoption of Water Quality Endpoints

In May 1999, EPA-Region III included Virginia's portion of the Chesapeake Bay and portions of several tidal tributaries on the 1998 Federal Section 303(d) list of impaired waters. All listed impaired waters are scheduled to have a Total Maximum Daily Load (TMDL) developed. At the same time, the Environmental Protection Agency is currently working on developing nutrient criteria nationwide to meet the objectives of the Federal Clean Water Action Plan. It is recognized that appropriate water quality goals for the Bay and estuaries need to be established through a consistent, unified approach. The Chesapeake Bay Program is currently working on a process to coordinate the existing cooperative Bay Program approach with the regulatory approach required under Section 303(d) of the Federal Clean Water Act. A key component of the process that is envisioned is the adoption of consistent environmental endpoints for water quality parameters, such as dissolved oxygen, total suspended solids and chlorophyll concentration. The timeline for reaching agreement on the environmental endpoints for the Chesapeake Bay and tidal tributaries is 2001. Once those endpoints have been adopted, they will need to be checked against the water quality improvements that are projected with the current recommended reduction goals to make sure that they are met. The current schedule calls for the re-evaluation of all tributary strategies to reflect new environmental endpoints and nutrient reduction goals in 2002. The reevaluation of nutrient and sediment goals for the James River will be consistent with this process. Additional detail on this topic can be found in the *1999 Annual Report on the Development and Implementation of Nutrient Reduction Strategies for Virginia's Tributaries to the Chesapeake Bay*.

Although the ultimate reduction goals for the James River may change in the near future, implementation of BMPs to reduce nutrient and sediment loadings to the James River should begin now. High sediment loading levels, lack of SAV, and high algae concentrations in the estuary are known water quality problems that will only worsen with delay. Given the high level of implementation that is required to substantially improve water quality, implementation today will only move us closer to the ultimate goal.

VII. References

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Table 4.4. Tidal James and Western Shore Percent Improvements from 1985 Conditions for Four Key Water and Habitat Quality Measurements and Associated Cost Estimates.

Scenario	Percent Loading Reductions from 1985 Conditions			Percent Improvements of Water Quality and Living Resource from 1985 Conditions				Virginia Cost Estimates (Millions)		
	Total Nitrogen (%)	Total Phosph. (%)	Total Sediment (%)	Surface Chlorophyll Tidal Fresh (%)	Deep Waters <3 mg/l DO (%)	Bay Grass Area (%)	Bay Grass Density (%)	Point Source Capital Cost	Non-Point Sources	Total
<u>1996 Progress</u>	11	36	2	23	16	210	95	$ 55	$ 3	$ 58
1996 Progress/Trib. Strat. Above	11	36	2	23	23	210	95	55	3	58
Current Limit of Tech. Sediment/Trib. Strat. Above	11	36	17	23	23	277	189	55	380	435
Extreme Sediment Reduction/Trib. Strat. Above	11	36	40	22	23	489	789	55	-	-
James AFL BNR Equiv./Trib. Strat. Above	15	38	6	25	-	210	108	126	-	-
James TF BNR Equiv./Trib. Strat. Above	32	36	2	52	-	354	200	-	-	-
James TF BNR Equiv. For N Only/Trib. Strat. Above	32	39	7	52	-	354	221	164	-	-
BNR Equivalent/Trib. Strat. Above	42	40	7	52	44	354	217	383	51	434
Midpoint 1996-Full Volun. Imp	30	47	6	42	N/A	334	227	-	-	-
Interim Bay Agreement Goal/Trib. Strat. Above	29	35	3	28	41	242	90	197	19	216
Full Voluntary Imp./Trib. Strat. Above	50	58	9	61	51	486	410	1,430	132	1,562
Full Voluntary Implementation	50	58	9	62	61	486	411	1,430	132	1,562
Current Limit of Technology	61	69	17	72	68	741	1861	2,342	465	2,806

1. Western Shore James includes Lynnhaven to Hampton Roads.
2. Total sediment load does not include bank loads directly to tidal waters.
3. Deep water failing habitat criteria under 1985 conditions was 4% of the total deep hypoxic waters in VA.
4. Grass beds were very sparse. Under maximum nutrient reductions, bay grass density attains only 1.4 g C/m as compared to the Western and Eastern Shore that attain above 50-100 g C/m, respectively.
5. Point source cost calculations include the HRSD-Chesapeake/Elizabeth STP from the Western Shore. All point source cost estimates are planning level estimates which are normally expected to be accurate +50% to –30%.
6. Nonpoint source costs reflect total installation cost for both state portion and stakeholder match but do not reflect the technical assistance and maintanance cost of the best management practice.
7. AFL = Above Fall Line; BFL = Below Fall Line; TF = Tidal Fresh; BNR = Biological Nutrient Removal

Table 6.1 Nonpoint Source BMPs for James River Basin (James & Western Coastal)
Based on Implementation of Scenario Options Developed via Tributary Teams

BMP Treatment	units	Year 1996 Status Coverage	Percent	Sediment Reduction	Year 1998 Status Coverage	Percent	Sediment Reduction	Year 2000 Projection Coverage	Percent	Sediment Reduction	Low Scenario Coverage	Percent	Sediment Reduction	High Scenario Coverage	Percent	Sediment Reduction
Farm Plans	acres	254,871	21.1%	26,573	285,035	23.6%	30,034	315,199	26.1%	33,495	0		0	719,942	59.7%	84,784
Nutrient Management	acres	92,035	15.5%	-----			-----			-----			-----			-----
Agricultural Land Retirement	acres	12,104	1.0%	4,702	15,646	1.3%	6,251	19,187	1.6%	7,800	0		0	70,179	5.8%	32,283
Grazing Land Protection	acres	7,879	1.3%	-----	12,382	2.0%	-----	16,885	2.7%	-----	0		-----	90,742	14.8%	-----
Stream Fencing	linear feet	634,715	-----	301	683,398	-----	326	732,082	-----	350	0	-----	0	10,596,096	-----	4,518
Stream Stabilization	linear feet	36,024	-----	93	42,235	-----	102	48,446	-----	110	0	-----	0	605,720	-----	1,382
Cover Crops	acres	8,429	2.8%	854	12,316	4.0%	1,424	16,204	5.3%	1,993	0		0	99,874	32.8%	10,413
Grass Filter Strips	acres	997	-----	492	1,037	-----	600	1,078	-----	709	0	-----	0	10,814	-----	10,072
Woodland Buffer Filter Area	acres	34	-----	59	144	-----	321	254	-----	583	0	-----	0	7,547	-----	12,083
Forest Harvesting	acres	45,363	70.0%	37,796	45,363	70.0%	37,796	45,363	70.0%	37,796	0		0	45,363	70.0%	37,796
Animal Waste Control Facilities	systems	32	-----	-----	38	-----	-----	42	-----	-----	0	-----	-----	0	-----	-----
Poultry Waste Control Facilities	systems	37	-----	-----	54	-----	-----	73	-----	-----	0	-----	-----	0	-----	-----
Loafing Lot Management	systems	4	-----	-----	8	-----	-----	12	-----	-----	0	-----	-----	0	-----	-----
Erosion & Sediment Control	acres	9,330	51.6%	10,424	9,330	51.6%	10,424	9,330	51.6%	10,424	0		0	9,330	51.6%	10,424
Urban SWM/BMP Retrofits	acres	0	0.0%	0	0		0	0		0	0		0	0		0
Urban Nutrient Management	acres	0	0.0%	-----			-----			-----			-----			-----
Septic Pumping	systems	0	-----	-----		-----	-----		-----	-----		-----	-----		-----	-----
			Subtotal Tons Reduced:	81,296			87,278			93,260			0			203,755
	Buffers (acres) implemented under CREP:	8,848	Reduces:	-----			-----			-----			15,389			15,389
	Wetland restoration (acres) under CREP:	1,071	Reduces:	-----			-----			-----			537			537
			Total Tons Reduced:	81,296			87,278			93,260			15,925			219,680
			Adjustment for Land Use Changes:	11,877			11,877			11,877			11,877			11,877
			Adjusted Reduction:	69,419			75,401			81,384			-11,877			191,879
			Total Nonpoint Reference Load:	2,076,515			2,076,515			2,076,515			2,076,515			2,076,515
			Percent Reduction:	3.3%			3.6%			3.9%			-0.6%			**9.2%**